DEPARTMENTS OF THE ARMY, AND THE AIR FORCE ***ARMY TM 5-852-2***
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ARCTIC AND SUBARCTIC CONSTRUCTION SITE SELECTION AND DEVELOPMENT

CCB Application Notes:

1. Character(s) preceded & followed by these symbols (+ +) or (+ +) are super- or subscripted, respectively.
   EXAMPLES: 42m+3+ = 42 cubic meters
   CO+2+ = carbon dioxide

2. All degree symbols have been replaced with the word deg.

3. All plus or minus symbols have been replaced with the symbol +/-.

4. All table note letters and numbers have been enclosed in square brackets in both the table and below the table.

5. Whenever possible, mathematical symbols have been replaced with their proper name and enclosed in square brackets.

SITE SELECTION AND DEVELOPMENT

LIST OF FIGURES

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*This manual supersedes TM 5-852-2/AFM 88-19, Chapter 2, dated 8 July 1966.

CHAPTER 1

GENERAL

1-1. Purpose.

This manual describes the procedure for selecting sites for military facilities in arctic and subarctic regions.

1-2. Scope.

The procedure is applicable to both Army and Air Force facilities.

1-3. References.

Appendix A contains a list of references used in this document.

1-4. Introduction.

The importance of the proper selection of a construction site in arctic and subarctic regions cannot be over-emphasized. The type of data to be collected for the selection of a site is essentially the same as that used for engineering design in temperate regions, but more detailed information is essential. It is not feasible to prescribe the detailed information required for a given site selection problem as each project requires judgment in the development of an adequate program of investigation and analysis; therefore, only the basic principles and considerations are included here. In addition, operational requirements of the future using agency, or other similar considerations beyond the scope of this manual, may impose unusual and unforeseeable requirements. Observations made in arctic and subarctic regions of North America form the basis for this manual, and while local details may vary considerably, the basic concepts presented are generally applicable.

1-5. Personnel.

Personnel used in site selection and development should be cognizant of engineering problems peculiar to arctic and subarctic regions and be familiar with airphoto interpretation. To ensure that the best possible site is selected and that the greatest amount of accurate and detailed information is obtained, the combined effort of a number of specialists is essential. Interpretation of aerial imagery and photography requires trained, experienced interpreters. These specialists should be allowed to participate in the field verification program to enhance their understanding of the terrain patterns that they mapped on the air-photos. For an important installation, personnel should include the airphoto analyst who has worked on the project, a coordinator who is a civil engineer familiar with the immediate and ultimate uses of the installation, a geotechnical engineer, a civil engineer (hydologist), a geologist, and an ecologist. For ground and subsurface surveys and for collection of data for design purposes, the following should be available, in addition to those listed above: a survey crew and party chief, a drill crew and foreman, and a local guide. Frequently, crews will be required to go into the field with preliminary soils maps and airphotos as the only means of orientation. In undeveloped regions where readily identified cultural objects, such as roads, structures, and cleared areas are absent; field crews should be able to identify landforms on the ground and on airphotos to aid in their interpretation.

CHAPTER 2

DATA ACQUISITION

2-1. Data required.

The information required for a given site varies considerably according to the size and importance of the proposed installation, its geographical location, and whether the facilities to be provided are in an unmapped area or are merely extensions of existing facilities. Important considerations are discussed in the following paragraphs.

a. Climate. Data should be obtained on temperature, precipitation, humidity, wind direction and velocity, and on the frequency and magnitude of severe storms. Temperature information should be obtained so that freezing and thawing indexes can be computed, so that depths of freeze and thaw can be estimated and the possibilities of degradation or aggradation of permafrost can be determined (see TM 5-852-6/AFR 88-19, Vol. 6).

b. Topography. Accurate topographic information is always necessary, including data on surface features and vegetative cover. Information necessary for planning drainage, roads, and camp layouts must be obtained. In investigations for potential airbases, topographic information must be obtained for the determination of flight hazards, for locating runways in positions involving a minimum amount of earthwork, for future snow removal operations, and for providing good flight approach angles. For structures adjacent to bodies of water, information on shorelines, harbor lines, high-water marks, and wave action is important.

c. Access. The availability of existing commercial and military ground, water, and air routes for the transportation of personnel and materials, and the location of way stations and terminals, as well as prospective sites for such facilities, must be determined. Information on existing or abandoned access roads should be obtained. Controlling navigable depths of rivers, lakes, and harbors should be determined where water transportation is contemplated. Data on the beginning and end of shipping seasons should be obtained where shipment of materials, equipment, and supplies by oceangoing vessels may be scheduled. Availability of smooth water for the landing of float planes should be determined. Data required for the selection of vehicles to be used for overland transportation during winter and summer should be evaluated.

d. Hydrology. Where a structure is to be located near a river, information on stream-flow variations throughout the year and on levels and frequency of flooding are of substantial importance for proper selection of the site. Information on ice-forming characteristics of the stream and on locations of previous ice jams should be obtained. In any structure or installation, drainage is an important consideration. The usefulness of existing drainage courses for the removal of excess storm water and wastes should be defined. Where applicable, the position of the water table and patterns of subsurface flow should be determined (see TM 5-852-7/AFR 88-19, Vol. 7).

e. Geology. Accurate surface and subsurface information is of great importance, and in many instances may be the determining factor in the selection of a site. Well-drained gravels and sands are frequently found in coastal plains, river terraces, glacial deposits, and outwash plains. Such soils are generally ideal for almost any type of construction in arctic and subarctic regions since they are generally free of ground ice, and thus thawing is not a major problem. Any type of construction is arctic and subarctic regions will be potentially troublesome if located on frost susceptible soils, such as clays and silts, unless ground-water conditions are exceptionally favorable. Where such foundation materials must be built upon, it is usually necessary to employ special precautions to maintain structural stability. These precautions are discussed in TM 5-852-4/AFR 88-19, Vol. 4, TM 5-852-5/AFR 88-19, Vol. 5, and TM 5-852-6/AFR 88-19, Vol. 6. Soils information must be obtained to a degree commensurate with the importance and size of the proposed structures. The usual tests, such as mechanical analysis, density, moisture content, and Atterberg limits for various horizons are minimum requirements, and additional tests such as permeability, consolidation, shear, and compaction tests are frequently desirable. Knowledge of the extent and nature of the permafrost where ice segregation occurs is vital. The depth and thickness of the permafrost layer, the depth of the annual frost zone, and the nature of the soils present in the permafrost and in the active layer must be determined. Information as to whether the permafrost in the active layer contains massive ground ice and whether it is homogeneously or heterogeneously frozen must also be obtained. Seismic design of buildings will be determined in accordance with TM 5-809-10/NAVFAC P-355/AFM 883, Chap 13.

f. Water supply and sanitation. Information should be obtained on the feasibility of developing a water supply for the needs of the installation. Pumping tests and water analyses should be made for potential wells. In some instances a dam site may have to be selected for impounding water. In addition to determining sources of potable water supplies and possible means of waste disposal, location conditions and regulations should be examined to avoid conflict. If water supply is to be developed from surface water, possible pollution sources should be examined. It may prove necessary in the Arctic to develop water supplies from two different sources, one for summer and one for winter. For example, where ground-water supplies cannot be developed and surface sources freeze in the winter, the surface source may be used during the summer, while melted snow or ice or storage tanks may have to be the source of supply in winter. The ability of a stream or a body of water to dilute sewage should be investigated to determine the degree of waste treatment that may have to be provided (see TM 5-852-5/AFR 88-19, Vol. 5).

g. Construction materials. Knowledge of the location of suitable sources of rock or rock deposits, gravel and sand for aggregates, and of stands of usable timber is normally essential. The nearest points at which non-native materials and supplies can be obtained should also be determined.

2-2. Data sources.

In the selection of a suitable site for military installations, information is usually available for the identification of general areas that may be suitable as potential sites (maps, aerial imagery). To identify the specific site within a general area, more detailed information is required, which may or may not be available.

a. Reports and records. Reports published by various government agencies, engineering firms, and researchers, etc., that give information on the characteristics of the terrain and on the climate, hydrology, and geology should be thoroughly examined. If no records of streamflow exist, quantities of flow will have to be estimated on the basis of climatic conditions and basin characteristics. In the absence of recorded climatic data, approximations will be prepared based on the best evidence.

b. Maps. The availability of adequate maps is essential to the selection of the site for any structure. In the more populated areas a wide variety of maps can be found. Among these are U.S. Geological Survey quadrangle sheets, which are prepared at convenient scales and contour intervals; U.S. Geological Survey base maps, which show the general features of regions; geological maps prepared by the Geological Survey and by local government agencies; agricultural soil survey maps; controlled airphoto mosaics; military maps of various types; and Federal Aviation Agency aeronautical charts. In unmapped areas, site selection is more difficult because of the additional reconnaissance and surveys required.

c. Aerial imagery. Airphotos and satellite imagery can be used to locate boundaries of soils having different characteristics and the extent of frozen and unfrozen soils, and to predict the engineering characteristics of soils in a given area. Airphotos can also be used to eliminate selection of totally undesirable areas and to suggest possible usable sites. Because of the constant advances in the techniques of acquiring and analyzing aerial imagery and the increased availability of this imagery, a significant amount of work in the site selection procedure can now be accomplished by using these types of data.

Therefore, in this manual considerable emphasis has been placed on the acquisition and use of aerial imagery in the site selection process.

d. Aerial reconnaissance. Reconnaissance flights are especially valuable in initial regional studies to obtain data on such factors as flooding and icing conditions, presence of flight hazards, possible temporary construction camp locations, possible access route locations, suitability of lakes and clearings for landing small aircraft, and military considerations, such as logistics and defense. Large areas can be covered in a relatively short time and the least desirable sites eliminated.

e. Ground reconnaissance. The purpose of ground reconnaissance is to check all information previously collected, to obtain data that are not otherwise available, and to select the best site if more than one potential site is available.

f. Subsurface explorations. The primary objectives of foundation explorations in arctic and subarctic regions are to obtain data on, first, the boundaries of frozen and thawed zones within the depth influenced by construction activities, second, the amount and mode of occurrence of ice in frozen soil, and, third, the composition and properties of the soil itself. The type of explorations is dictated to a large extent by the relative inaccessibility of many northern areas and climatic limitations. In addition, special techniques are frequently required for explorations in frozen ground because the strength of frozen soils decreases rapidly with an increase in temperature toward the 32 deg f isotherm.

CHAPTER 3

SITE SELECTION

3-1. General.

a. Aerial imagery. The general remoteness and undeveloped nature of much of the world's arctic and subarctic regions pose special problems in acquiring adequate terrain information to plan and design both civil and military projects in these areas. Aerial imagery acquisition and analysis is a valuable tool for organizing and implementing a site selection process at the early stages of construction planning.

b. Imagery analysis. The procedures developed to analyze terrain through the use of aerial imagery are, in effect, processes of terrain evaluation and elimination. Starting with a reconnaissance overview of a large area using satellite imagery, many areas can be eliminated from further consideration because of topographic, drainage and access problems. Conversely, potential sites can be identified. From these possibilities, the best potential sites can be selected for a more detailed, refined analysis using stereoscopic aerial photography. Ultimately, a detailed data base of terrain information can be developed for a ground sampling program and for the placement of specific structures.

3-2. Regional analysis procedures using satellite imagery.

a. General. The military services of the United States have access to a vast array of satellite acquired imagery through agencies within the Department of Defense. However, the images produced by these systems are classified, and the use or potential use of these materials will not be addressed in this manual. Instead, the unclassified, easily obtainable imagery products of the NASA/Landsat satellite program, under the direction of the National Oceanic and Atmospheric Administration (NOAA) and formerly under the United States Geological Survey (USGS), will be discussed in this manual.

(1) Digital data from the Landsat Multispectral Scanner Subsystem (MSS) sensor have been

available for evaluation by the user community since July 1972. The MSS is a line-scanning device that obtains data for an area of 13,225 square miles (115 miles on a side) at a resolution of approximately 1.1 acres. Data are obtained in four spectral bands-two in the visible (0.5 to 0.6 [MU]m [micrometers = microns] and 0.6 to 0.7 [MU]m and two in the near infrared (0.7 to 0.8 [MU]m and 0.8 to 1.1 [MU]m).

(2) In the 1982 the Thematic Mapper (TM) sensor was launched on Landsat 4. The Thematic Mapper sensor is a mechanical line scanner device, similar to the MSS. However, it scans and obtains data for six scan lines in both directions during the scanner sweep. The MSS only scans and obtains data in one direction for six scan lines at a time. The TM acquires data at a resolution of approximately 0.22 acres for seven spectral bands ranging from the blue part of the spectrum into the spectrum into the thermal infrared region (0.45 to 0.52 [MU]m, 0.52 to 0.60 [MU]m, 0.63 to 0.69 [MU]m, 0.76 to 0.90 [MU]m, 1.55 to 1.75 [MU]m, 2.08 to 2.35 [MU]m, and 10.4 to 12.5 [MU]m at approximately 400 feet).

(3) In February 1986, the French launched the Systeme Probatoir d'Observation de la Terre (SPOT) satellite. This operational satellite is in a near-polar orbit, similar to the Landsat satellites. There are two High Resolution Visible (HRV) sensors on SPOT. The instrument is also pointable, imaging 26 degrees on either side of nadir. There are two modes of instrument operation-the multispectral and panchromatic.

(4) The multispectral mode covers three spectral regions-two in the visible (0.50 to 0.59 [MU]m, 0.61 to 0.68 [MU]m) and one in the near infrared (0.79 to 0.89 [MU]m) at a resolution of approximately 0.1 acres. The panchromatic (black and white) mode covers a wide band ranging from 0.51 to 0.73 [MU]m at a resolution of approximately 0.025 acres. When the satellite is pointed at nadir, both HRVs image 37-mile wide areas. The satellite can point off to either side of nadir at 0.6-degree increments, up to 26 degrees on either side of the orbital path. The satellite can thus image any area within a 589 mile swath centered over the orbital path. This allows for acquisition of stereo imagery and for more revisit opportunities over an area of interest. A maximum of six stereopairs can also be obtained during the 26-day cycle.

(5) The satellite data are acquired in a digital mode from the MSS, TM and HRV sensor systems and can thus be analyzed by a computer. The geometric accuracy of the data is to within one-half of a pixel. With this accuracy, the digital data from the sensor systems can be referenced to any coordinate system.

b. Obtaining Landsat images. Reproductions of Landsat imagery can be obtained from the Earth Observation Satellite Company (EOSAT), 4300 Forbes Blvd., Lanham, MD 20706. A computer listing of available images will be sent along with an order form and a key to explain the information in the listing. The computer listing will identify all images and photographs available over op close to an area of interest. Each image or photograph will be described in two printed lines on the computer listing. A number of entries may be listed, depending on the size of the area selected and the restrictions of the supplemental data. Imagery or photography may be available from more than one source (e.g., from Landsat, Skylab, NASA aircraft, or aircraft of the U.S. Geological Survey or other agencies) all of which differ significantly in sensor or camera characteristics. Thus, each entry on the computer listing should be carefully studied to determine the best selection for the purposes under consideration. The first line of each entry on the computer listing gives data characteristics, along with information required for subsequent ordering. The second line of information denotes the geographic coordinates (by latitude and longitude) of each individual image.

c. Method of using Landsat images. Landsat images provide an ideal basis for conducting a regional terrain analysis of an area of interest. To demonstrate the use of these products, a hypothetical terrain analysis for site selection has been conducted and is portrayed in the series of illustrations that follow. Based on the computer search for a suitable Landsat image, the four bands of imagery of an area of Alaskan terrain were ordered and appear as figure 3-1. The false color composite (shown in black and white in fig. 3-2) was formed by the superpositioning of bands 4, 5 and 7 through corresponding filtration. When available, the false color composite should be ordered for site selection;

otherwise, either bands 5 or 7 would be usable.

(1) The Landsat series of images do not produce stereoscopic images. There is only about 10% endlap between frames. At high latitudes where orbital paths converge at the pole, sidelap stereo can be observed between images of adjacent orbits. However, because of the high altitude at which these images have been obtained, only large, mountainous features tend to express much sense of topographic relief. The primary use of these Landsat images for analyzing terrain is to conduct a monoscopic (not stereoscopic) pattern analysis.

(2) The overlay presented as figure 3-3 is a result of a monoscopic pattern analysis of the false color composite Landsat image (fig. 3-2). The legend briefly describes the categories of terrain information derived by analyzing patterns on the Landsat scene. Much of the area consists of terrain features that are normally unsuitable for building sites, such as areas of high elevations (mountainous terrain), or thermally unstable and sensitive areas (thaw lakes and permafrost zones). By considering the large river that traverses the scene as a possible way to get into the area, an area of interest to be studied in greater detail was selected. This area is enclosed in the rectangle on the overlay. Of particular interest was the river, its broad floodplain, and the dissected terrace area, which might be suitable for a construction site. Therefore, based on a monoscopic pattern analysis of a large area (approximately 13,225 square miles), involving the delineation of photo patterns associated with topography, drainage and permafrost conditions, an area was selected for further, more detailed study (with aerial photography). The selection should be based on the scale and scope of the project.

3-3. Localized area analysis procedures.

a. Obtaining existing stereoscopic aerial photography. While there still are areas in the earth's arctic and subarctic regions where no aerial photography has ever been acquired, it is more usual to find that there is adequate airphoto coverage of these regions. The primary reason for photographing these remote areas in the first place was to produce maps. More recently, the exploration for natural resources in arctic and subarctic areas has led to even more aerial photography coverage. Aerial photography aimed at mineral and other natural resource explorations has been, and is being, done by both governmental and private organizations for many of the countries bordering the Arctic. In the United States, for example, the U.S. Geological Survey, Bureau of Land Management, National Park Service, State of Alaska, and the Department of Transportation have flown aerial photography missions in Alaska, so have many major U.S. oil companies and the Alaska Pipeline Service Company (Alyeska). An increasing amount of aerial photography is being acquired for environmental research projects being done in arctic regions.

(1) In addition to these sources, the Defense Mapping Agency, the Defense Intelligence Agency, the U.S. Air Force and U.S. Navy periodically acquire aerial photography of arctic areas. Unfortunately, there is no one organization that keeps up to date on all the aerial photography produced in these regions. As far as the United States is concerned, the EROS Data Center of the USGS at

Figure 3-1: Four Spectral Bands Of Landsat: PHOTO NOT INCLUDED

Figure 3-2: Landsat False Color Composite Composed Of Bands 4, 5, and 7: PHOTO NOT INCLUDED

[retrieve Figure 3-3: Terrain Analysis Overlay To Landsat False Color Composite Image]

Sioux Falls, South Dakota, probably contains the most comprehensive inventory of aerial imagery in its data bank.

(2) A number of techniques are used to indicate and identify what particular aerial photograph covers what particular area. A common method used by the USAF and a number of other government, as well as commercial, agencies is the "flight line map." The centerlines of strips of aerial photography

are drawn on a base map, with the photo mission, date, scale, emulsion and camera specifications usually annotated as part of the legend. Usually, the ends of each flight line are also annotated with film roll number and exposure number. By use of a flight line map that covers the area of interest, the exact exposure numbers can be identified to place an order for photographic prints.

(3) A second method uses a "photo index sheet" where all of the aerial photographs taken of an area have been roughly pieced together with all exposure numbers showing. This mosaic is photocopied and reduced to a convenient size (the U.S. Department of Agriculture uses a 20- by 24-inch size), which can be used to order the aerial photographs required.

(4) A third method, becoming more common, is conveying all aerial photography information through a computer printout. This method is parallel to the previously illustrated method of ordering and determining satellite imagery coverage. In this instance, a search is made by the EROS Data Center for specific airphoto coverage of an area based on geographic coordinates. Upon the completion of the search, a computer printout is received and the user can select his photo.

(5) To ascertain the coverage of certain photos listed on the printout, a rough flight line coverage overlay should be developed on a suitable base map. This process is illustrated in figure 3-4, where the data have been transposed into a photo coverage overlay based on a 1:250,000 topographic map. Since, in this case, the computer printout had indicated each corner covered by a strip of photography, the overlay has been constructed to show the total area covered by each flight line as well as all the flight lines needed to cover the desired area.

b. Acquisition of new aerial photography. Quite often it is desirable, and at times necessary, to acquire new aerial photography either to supplement existing photos or in case no suitable existing aerial photography can be obtained. In requesting new photography the following items should be considered.

(1) Types of photographs. Nine- by nine-inch oblique and vertical photographs are most commonly used. Low-altitude obliques are useful for evaluation studies and illustration. Vertical stereopairs greatly aid terrain interpretation.

(2) Focal length of lens. A lens with a short focal length should be used in flat areas to increase the apparent depth perception in the stereoscopic image so that minute changes in relief are resolved. A 6-inch lens is recommended. In hilly or mountainous terrain, a 12-inch focal length lens is most practical.

(3) Type of film. Panchromatic (black and white) film is widely used for a basic photo coverage. Color aerial film and color infrared film are being increasingly used, especially over selected, environmentally sensitive areas. Color infrared film is normally used to produce positive transparencies rather than paper prints.

(4) Types of filter. Filters are used to cut atmospheric haze and to accentuate tonal differences. Yellow haze filters, often referred to as "minus blue" filters, are used with both panchromatic and black and white infrared films.

(5) Overlap and sidelap. Photography intended for use in mosaics and for detailed stereoscopic interpretation should have a 60 percent overlap between frames along a flight line and a 30 percent sidelap between flight lines.

(6) Location. Geographical coordinates bounding the area should be indicated. Flight lines plotted on large-scale topographic maps are of considerable value to the aerial photographer. If possible, checkpoints should be established on the ground to aid the aerial photographer.

(7) Scale. The scale of photography is normally specified in terms of the representative fraction (RF), which is equal to the flying height (in feet) of the aircraft above mean terrain, divided by the focal length (in feet) of the aerial camera. For example, the scale of photography flown at 6,000 feet with a 6-inch lens is 1:12,000. For regional coverage and analysis, scales of 1:40,000 to 1:80,000 are recommended. For local, highly detailed analysis, scales as large as 1:10,000 to 1:20,000 are useful.

(8) Season for photography. Usually, the summer season in arctic areas is specified because of

extended daylight and a lack of a snow cover in most areas.

(9) Annotation of negatives. Every aerial photograph should be annotated with at least an exposure number. Each end photo of a flight line should be annotated with roll number or line number, scale, and date. To adequately control numerous aerial photography projects, a project symbol should be annotated on each photo.

Figure 3-4: Photo Flight Line Overlay To A 1:250,000 Topographic Base Map: PHOTO NOT INCLUDED

(10) Type of prints. For most interpretation work, semi-matte finished (9- by 9-inch) contact prints on RC (resin coated) paper are advisable. The option to request enlargements from (9- by 9-inch) aerial negatives is available, if needed for planning.

(11) Flight line map or photo indices. It is very desirable to obtain or create a flight line map or a photo index map of the requested photo coverage.

c. Assembling the stereoscopic aerial photography data base. Upon receipt of the aerial photography, all of the photos must be trimmed to the edge of the actual image. In some instances, pertinent annotations regarding exposure number, scale, date, etc., are contained in these areas, which must be trimmed from the prints when the mosaic is prepared. At least the exposure numbers should be transferred inside the image boundary. An example of this supplementary annotation can be seen on some of the strips of photos on the stereomosaic in figure 3-5.

(1) To begin creating a stereoscopic airphoto mosaic, a suitable base material upon which the mosaic can be stapled must be chosen. Celotex, foam core and "chip board" are all suitable.

(2) Six strips of photography have been used to create the example mosaic (fig. 3-5). Note that photos have been positioned end to end, with about a 10% overlap in each of the strips. Also note that each strip overlaps the adjacent strip by about 30%. The photos not laid down as part of the mosaic are set aside and labeled to show in which strip they belong. These are used for stereoscopic analysis in conjunction with the completed mosaic. It is important to lay out the strip of photos in a way that allows each print number to show, so that the unmounted stereo pair photos that have been set aside can be used in their proper sequence. Since each photo is slightly distorted in scale from the center outward, the trick in laying a stereoscopic photomosaic lies in allowing a very small degree of offset between every photo and strip, so that large offsets are not created toward the periphery of the entire mosaic. Also, by laying out the center strip or two first, with as close a match as possible, any accumulation of offset is thereby forced to the outer edges of the mosaic.

(3) All six strips of photos are laid out loosely in this manner, with weights to hold them in position for a final adjustment. This final adjustment is made by making slight shifts among all the photos to obtain a best match. Then the mosaic can then be stapled fast to the base.

d. Terrain and environmental factor mapping. It is not the intent of this chapter to the teach photo patterns and corresponding ground conditions for arctic and subarctic terrain features. A more comprehensive treatment of this aspect of photo analysis can be investigated through the references shown in the Bibliography. The following will discuss the general analysis process, which is described in greater detail in these references.

(1) The stereoscopic mosaic is used in conjunction with a stereoscope and the unmounted alternate (stereo pair) photos of each strip. The exposure numbers on each print are used to locate the proper stereo pair to view a particular area stereoscopically. The entire mosaic can be viewed in the third dimension using this technique.

(2) The process of analyzing and interpreting stereoscopic aerial photography draws upon the background, experience and knowledge of the analyst or, better yet, a team of analysts with knowledge of several disciplines. It is an application of logic and reasoning to synthesize data obtained by observation and inference. It is based on a recognition of natural relationships (physical, biological and cultural) as expressed by key pattern indications present in the image.

(3) A systematic approach to airphoto pattern analysis embodies three phases: first, a regional study; second, a detailed stereoscopic study of pattern elements; and third, a final interpretation of results to answer a posed question or solve a problem.

(a) A regional study, such as has been conducted using the example Landsat image, considers the broad, overall aspects of an area in terms of physical makeup of the landscape; origin, type and distribution of materials; broad natural vegetation assemblages; surface hydrology; and land use patterns. The results of a regional study give a team an overview and assessment of an area in which numerous landscape patterns can be recognized, delineated and associated. The study also serves to suggest areas within the region that might be most suitable for potential site selection and where more detailed study should be undertaken by using larger scale imagery.

(b) A regional study is followed by a detailed stereoscopic study of smaller areas selected from the regional analysis. Here each pattern element is systematically studied and evaluated to accurately determine the character of the physical, biological, and cultural components of the landscape. Landforms, surface drainage, depositional and erosional aspects, photographic tones, and biological and cultural aspects are all observed and evaluated as elements of the photo pattern. This detailed analysis, coupled with existing information in the form of published reports, surveys,

Figure 3-5: Stereoscopic Airphoto Mosaic: PHOTO NOT INCLUDED

or maps, can be merged effectively into the "environmental data base" necessary to complete the final interpretive phase of the study.

(c) Upon completion of this second phase of study, the analysis team should consider going into the field to check its work and to iron out any remaining trouble spots. The field correlation of the original photo analysis by the team members is an extremely valuable exercise, which invariably results in an upgrading of individual and team capabilities.

(d) Finally, the interpretive phase of the study is reached where all acquired information is interpreted in the light of a specific problem or question. Only then has enough pertinent information been assembled to warrant the answering of the primary question posed about the study area.

e. Site evaluation process. Understanding the relationship between the visible indicators of permafrost and severe frost activity on the aerial photography and actual ground conditions will allow the team to obtain a considerable amount of accurate and detailed information through the photographic analysis process. Detailed stereoscopic study of high quality aerial photos assembled into a stereoscopic photomosaic will result in locating, identifying, and evaluating many of the features necessary to determining ice-soil relationships and the thermal regime. Chief among these are topographic position, parent materials, surface drainage, vegetation, exposure to solar energy, and above all, the well-established indicators related to permafrost and frost action phenomena. Some of these indicators are polygons, button drainage, pingos, frost boils, altiplanation features, solifluction lobes and strips, stone rings, etc.

(1) Airphoto derived information is recorded directly on a series of Mylar or acetate overlays depicting categories such as landforms/soils/rocks, drainage, vegetation and associated wildlife habitat, land use and transportation, and frost/permafrost. These provide an environmental data base and are useful in all stages of project planning and development.

(2) For purposes of locating or sitting, the airphoto analysis technique offers much to the location engineer in terms of the following:

- A basis for understanding an area in regard to criteria governing the type of structure to be built.
- Information about likely problems because of the environmental stresses present.
- A basis for predicting environmental impacts likely to result during construction.

In the Arctic these are extremely important because of the often very sensitive thermal regime of the terrain.

(3) Considerable use can be made of airphotos during the design phases for structures, large installations and transportation systems. However, the designer needs detailed quantitative data such as composition, profile or stratigraphic characteristics, thickness and kind of mantle on bedrock, densities, bearing strength, surface and subsurface moisture, presence and type of frost-susceptible materials, thickness of the active layer, ice/soil relationships in the permanently frozen subsurface, and location and type of organic material, if present. The present state of the art does not permit obtaining quantitative data on any of these items by photo analysis or any other remote sensing means. However, the detailed analytical study of photo patterns will result in mapping the type, distribution, and general characteristics of soils and rocks; determining the complexity and uniformity of a deposit; determining the location and extent of surface water and suspected occurrences of

high subsurface moisture; discovering general permafrost location and characteristics; determining the location and general magnitude of frost activity in the active zones; and identifying and locating areas requiring concentrated attention for successful construction. Since the quantitative data can only result from field sampling and laboratory testing, the photos play an important role in planning the field sampling program.

(4) Individual factor overlays are presented that result after the photointerpreter has delineated photo patterns on the airphoto mosaic through the processes of stereoscopic viewing and analysis. Overlays depicting land forms, drainage, surface materials, vegetation, land use, and special factors such as permafrost can all be created separately. Examples of some of these overlays, prepared from the photomosaic (fig. 3-5), are presented as figure 3-6.

(a) Drainage overlay. The various patterns of drainage evident on this overlay reflect conditions of the bedrock and surface materials composing the terrain. All of the landform and permafrost boundaries on the following two overlays correspond to changes in the patterns of drainage. This drainage factor tends to be one of the most important factors to be mapped in any photo analysis study. Also, it should be the first factor to be mapped because it forces an analyst or team of analysts to view the entire area stereoscopically to delineate all the fine drainage detail. This, in turn, provides a necessary initial familiarity with the entire area.

[retrieve Figure 3-6a.: Individual Factor Overlays - Drainage]

[retrieve Figure 3-6b.: Individual Factor Overlays - Landforms]

[retrieve Figure 3-6c.: Individual Factor Overlays - Permafrost]

(b) Landform overlay and engineering materials delineation. The original scale of the photos used to create the stereoscopic photomosaic in figure 3-5 is 1:62,500, or 1 inch to the mile. At this scale, terrain information can be identified and delineated stereoscopically. However, reducing the 40- by 60-inch photomosaic and overlays to fit the format of this publication has caused very fine detail to be eliminated. The mapped features in this example include the following:

- MT (mountainous terrain), which occurs at high elevations, and has a thin soil mantle, with bare rock outcrops.
- HT (hilly terrain), which occupies areas flanking high elevations as ridges or spurs. "Horse tail" drainage can be associated with much of this pattern, which is suggestive of ice-rich silty materials.
- AF (alluvial fans), which are large, valley fill, coalescing fan deposits. Long slopes, flat gradients and "soft"-appearing dissection by surface drainage are indicative of ice-rich silty soils.

- SS (solifluction slopes), which are slopes flanking many of the mountains and larger hill masses composed of unconsolidated deposits, saturated with water released by thawing.

- TK (thermokarst), which occurs here in large, flat, ice-rich areas beyond the terminus of valley fill alluvial fans.

- FP/F (flood-plain/fine-grained deposits), which are ice-rich, silty deposits.

- FP/C (flood-plain/coarse-grained deposits), which are predominantly unfrozen, alluvial sands and gravels.

- TL (thaw lakes), which indicate thermally unstable materials developing into a lake-studded, low-lying planar surface.

- SD/AT (sand dunes lying upon an alluvial terrace), which are unfrozen sand dune deposits lying on a partially frozen alluvial terrace.

- CP (coalesced palsas), which are small hillocks on a planar surface caused by local upheaval of the active layer in a permafrost environment with fine, silty soils.

(c) Permafrost overlay. This overlay delineates the permafrostinfluenced terrain patterns from the non-permafrost areas. The overlay is more or less self-explanatory. This overlay, coupled with the landform and drainage overlays, would demarcate the alluvial deposits along the major river valley and the sand-dune-covered terrace inside the broad bend of the river as being the most promising areas to investigate on the ground for site selection purposes.

(d) Vegetation type and distribution overlay. From the scale of photography used in this example, no definitive identification of vegetation could be done. Special overflights to obtain imagery at scales larger than 1:10,000 would be required to evaluate the biological patterns of the landscape.

(e) Detailed permafrost features overlay. Likewise, even to observe the numerous patterns of permafrost (polygons, solifluction lobes, soil stripes, frost boils, etc.), much larger scales of photography have to be used. Only the gross effects of permafrost were observed and used in creating a general permafrost overlay for this example illustration.

CHAPTER 4

GROUND SURVEYS

4-1. General.

By using the overlays individually and in superposition, it is possible to design a ground sampling program. This program should take advantage of the fact that within each pattern boundary the conditions are generally uniform and that extensive sampling is not required within those boundaries. However, field investigation should be undertaken to verify that conditions in the area are as interpreted from the photos.

4-2. Ground reconnaissance.

Based on the terrain categories defined by airphoto analysis, a field study should be started. Inspection of the selected area from the ground is the only certain method of getting all necessary information for a particular site. It should include observations of soil, snow cover, vegetation, ground water, surface water, local sources of construction materials, and other pertinent information. Much valuable information regarding floods, icings, earthquakes, and landslides can often be obtained from local inhabitants. For ground reconnaissance, hand equipment, such as hand levels and augers, are generally used. For more comprehensive surveys, conventional surveying methods are employed. The extent and precision of the information to be obtained is determined by professional judgment.

a. Subsurface explorations. In the evaluation of a potential site in a permafrost area, the site location in relation to local topography and land forms is an important factor in helping to understand the character and nature of subsurface materials (see TM 5-852-8/AFM 88-19, Vol. 8). Data can be obtained by sounding rods and by percussion, rotary, and auger drilling. Adequate exploration, however, requires fairly continuous and undisturbed samples.

(1) Explorations made during the late summer or early fall may be necessary to determine the depth to the permafrost table, the location of which has an important role in most design studies and construction planning. From the standpoint of equipment mobility, the best conditions for reconnaissance and preliminary explorations in the more remote areas usually exist during the winter, while the ground surface is frozen.

(2) Probings by driving rods by hand or by use of a drill rig near the end of the thawing period are a rapid means of determining the location of the upper surface of permafrost over a large area. It is necessary to supplement probings by explorations in which soil samples are obtained for visual classification or laboratory tests. Unfrozen soils are sampled using techniques and equipment similar to those developed for the temperate zone (see App I of TM 5-818-1).

(3) Samples of frozen soils suitable for water content and classification tests can be obtained by power auger. Tungsten carbide cutting teeth on the base of augers give satisfactory service, if frozen material does not contain an excessive amount of cobbles or large boulders. It is not always possible by use of a power auger to obtain sufficiently undisturbed samples for determination of the intensity of ice segregation in soils. Relatively undisturbed samples of frozen silts, clays, and some fine, saturated sands can be obtained by drive sampling using a pipe with a tempered, sharpened cutting edge, or soil sampling tube, or by rotary drilling, using tungsten carbide sawtoothed core bits or diamond core bits.

(4) Soil that may appear to be unfrozen, especially in auger cuttings, may actually contain frozen water. If there is any doubt, the sample should be examined with great care. The soil should be warmed and carefully examined for a marked loss in strength accompanied by an apparent marked increase in water content. Such behavior definitely indicates that the sample initially contained frozen water.

(5) Borings are generally done without the use of casing except as necessary to prevent caving in the thawed portions of the hole. The test boring may be advanced from one sampling depth to the next either by churn drilling, using water for drilling fluid with additives as necessary to prevent freezing, or by rotary drilling, with a roller bit using precooled compressed air to blow the cuttings to the surface. The use of salt to depress the freezing point of the drilling fluid to a sufficiently low temperature for drilling and coring requires a considerable amount of salt, which dissolves ice in samples and often causes skin irritations. Arctic grade diesel fuel cooled by ambient air in winter or by mechanical refrigeration in summer has yielded mechanically and thermally undisturbed core samples of a wide variety of frozen soils and rocks. The use of chilled diesel fuel as the drilling fluid may be disagreeable to operating personnel because of its odor, but it reduces the thermal disturbance of the hole wall, increases wall stability, and markedly decreases the time required for installed temperature sensing cables to come to equilibrium. (This method is no longer used because of environmental considerations.)

(6) Samples obtained by drive sampling or cored by rotary drilling methods generally give adequate information on the nature and degree of ice segregation and permit an estimate of the magnitude of subsidence that would result upon thawing. A reliable, but slow and expensive, means of frozen ground exploration is the use of test pits, employing compressed air tools or drilling (or both) for excavation of frozen soils. Shape charges may be used to assist in excavation work. In frozen, gravelly soil, test pits may be necessary for determining the existence of segregated ice, either as buried ground ice or as pockets in frostsusceptible soils within the gravel deposit.

(7) Geophysical prospecting methods have been used to delineate permafrost bodies; however, procedures have not been fully developed to date. These methods can be used as a guide or in conjunction with exploratory drilling. Seismic and resistivity methods have proved to be most useful because the frozen interstitial water in soils and rocks causes greater changes in seismic velocity and electrical resistivity than in other geophysically measured properties. Seismic refraction techniques can be used to determine the extent and depth to the permafrost table. Theoretically, resistivity methods can

also be used to measure the thickness of permafrost bodies. The reliability of geophysical prospecting methods depends to a great extent upon experience of the personnel interpreting the results.

(8) The amount and type of soil information required depend upon the character of the structure or facility that is being planned at a particular location and the uniformity of soils and permafrost conditions. Where there are nonuniform conditions, such as spotty occurrences of permafrost or various soil types, the explorations should be spaced as closely as necessary to determine the extent of these conditions. Explorations should be carried to sufficient depth to obtain information for the entire zone that is estimated to be subject to future thawing as a result of the proposed construction. Subsurface explorations for the design of runways, taxiways, and roads should extend about 6 to 10 feet below final subgrade elevation in cut areas, and to the same depths below the existing ground surface in fill areas. A few holes should be carried deeper to determine the characteristics of the lower strata.

(9) When no cold air circulation can be provided beneath the floor, the depth of test holes beneath large heated structures, such as powerhouses or hangars, should be in excess of the theoretical depth of thaw, with a minimum depth approximately equal to the least width of the building. For building foundations where cold-air circulation can be provided, explorations should extend to a minimum of 10 feet below the theoretical depth of thaw and, in all cases, be carried to approximately 10 feet below the base of foundation support.

(10) In sporadic or discontinuous permafrost areas where a site is selected based upon the local absence of permafrost, great care should be taken to assure that small permafrost bodies are not overlooked.

b. Ground temperatures. Permafrost is defined on a temperature basis; therefore, a knowledge of the ground thermal regime is usually needed for design studies. Various possible temperature measuring methods are available, making use of probes in thermal equilibrium with the media whose temperature is to be measured. Three types of equipment commonly used are resistance thermometers, thermocouples, and thermistors, each dependent on the accuracy desired.

Thermocouples encased in plastic tubes and installed in drill holes have been used successfully for geothermal studies of permafrost and studies of the stability of structures built on and in permafrost or ice. Subsurface temperatures should be recorded in the summer and fall to observe the highest range of temperatures reached in the ground. Figure 4-1 shows how ground temperatures vary in a permafrost area having a mean annual temperature of 26 deg. F (Fairbanks, Alaska). In addition, observations essential for design are the rate and depth of thaw occurring under various terrain conditions, together with observations of ground movements because of freezing and thawing of the active zone.

[retrieve Figure 4-1: Typical Ground Temperatures, Fairbanks, Alaska]

APPENDIX A

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